Basic Biochemistry

A visual approach for college and university students

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Preface

Organisms function. In order to do this, they are organised. Anything which functions is organised, whether it is a motor car, a bacterium, the human body, a telephone network. Events which occur in them do not happen randomly but are directed according to a pattern.

It is a basic character of all organised systems that they require:

1. Structure – the structure carries the pattern which directs the function.
2. Energy – the energy is required to make the system function, or work, and also to build it and keep it in repair.

In organisms, the energy source – often carbohydrate or fat – is frequently used as part of the structure, and vice versa. So, sugars are a major energy source but are also used as the building material for plant cell walls; fats are also respired to produce energy but are part of membranes found in cells; amino acids are important units of the structural protein of skin and connective tissues but may also be used as an energy source.

These inter-relationships make the sorting out of the structure and function of living systems very complex. Their patterns are perhaps more easily grasped visually than descriptively. This book attempts the visual approach to biochemistry rather more than most others. Here and there it may labour the basic concepts more than many biochemists might think warranted. But the experience of the authors leads them to believe that many students, who are not making biochemistry their major study, often learn superficial complexities rather than basic simplicities.

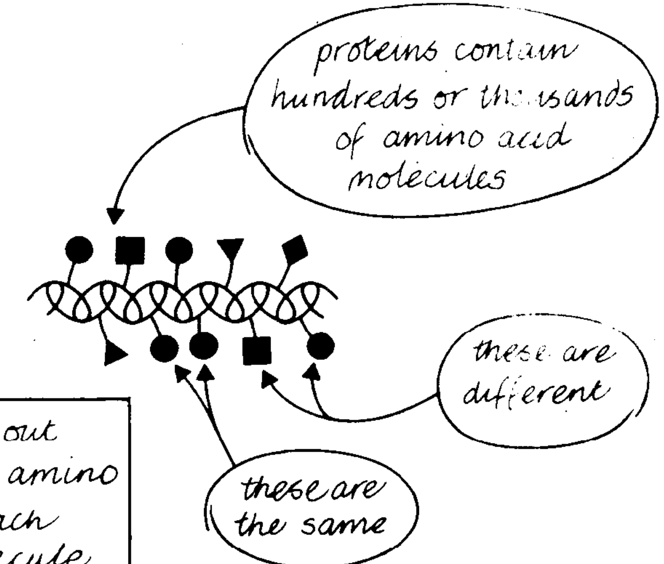
For this reason, the book is aimed not only at biochemists, but also at those students who are about to embark on the host of subjects which demand some biochemical knowledge. These range from home economics to agriculture, from botany to medicine. It is not meant particularly for students at universities nor those at technical colleges or polytechnics, nor for very bright sixth-formers taking S level. We, the authors, however, hope that it will be found of some use as a groundwork by some students among all of these classes.

Contents

Part I Compounds in the Cell

AMINO ACIDS AND PROTEINS

- Amino acids are joined together in chains to make proteins.



- The 20 amino acids which are found in proteins are called the **monomers**: all proteins are **polymers**.

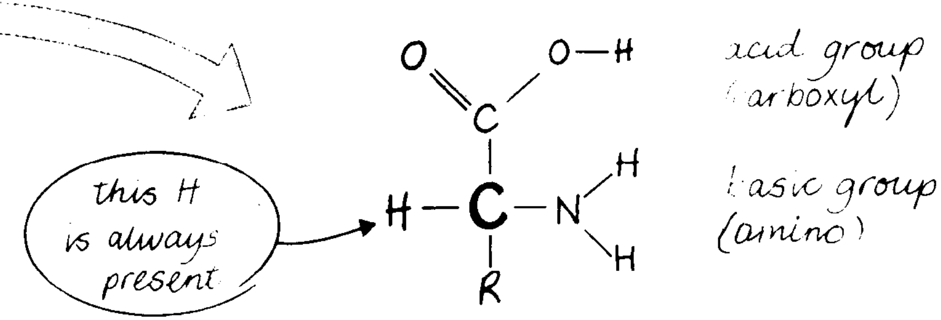
there are about 20 different amino acids in each protein molecule

- The amino acids are made of C,H,O and N (except 3 which also contain S).

for example

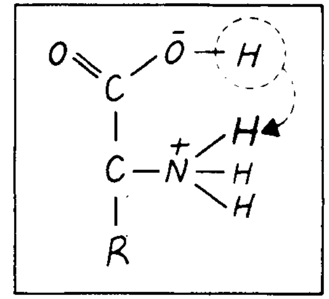
$C_2H_5O_2N$ glycine
$C_6H_{14}O_2N_2$ lysine
$C_3H_7O_2NS$ cysteine

- Each amino acid has an acidic group and a basic group in its molecule. These groups are attached to the same C atom.

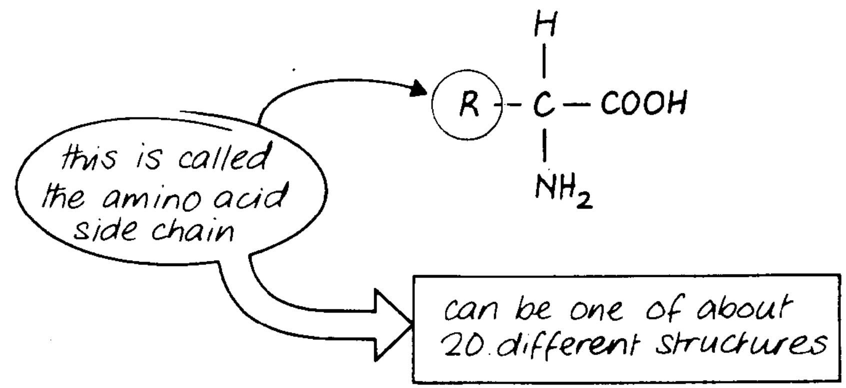


- Compounds whose molecules have both basic and acidic properties are called **amphoteric** compounds.

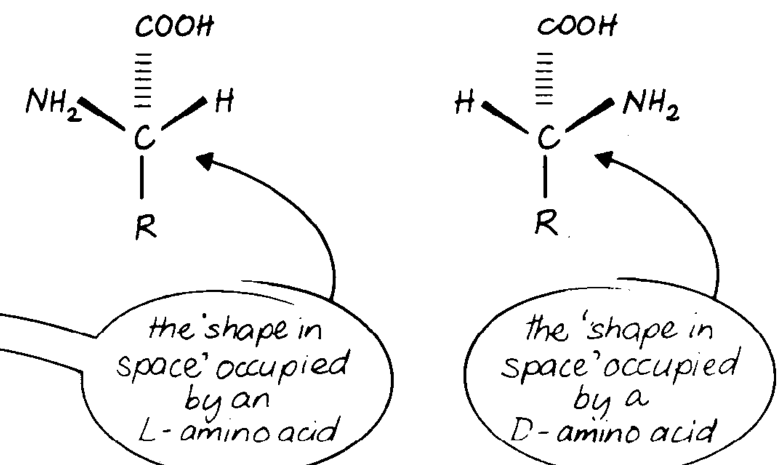
- Molecules of amphoteric compounds may form 'internal salts'; they are called **zwitterions**



- Amino acids are different because they have different **R** groups.

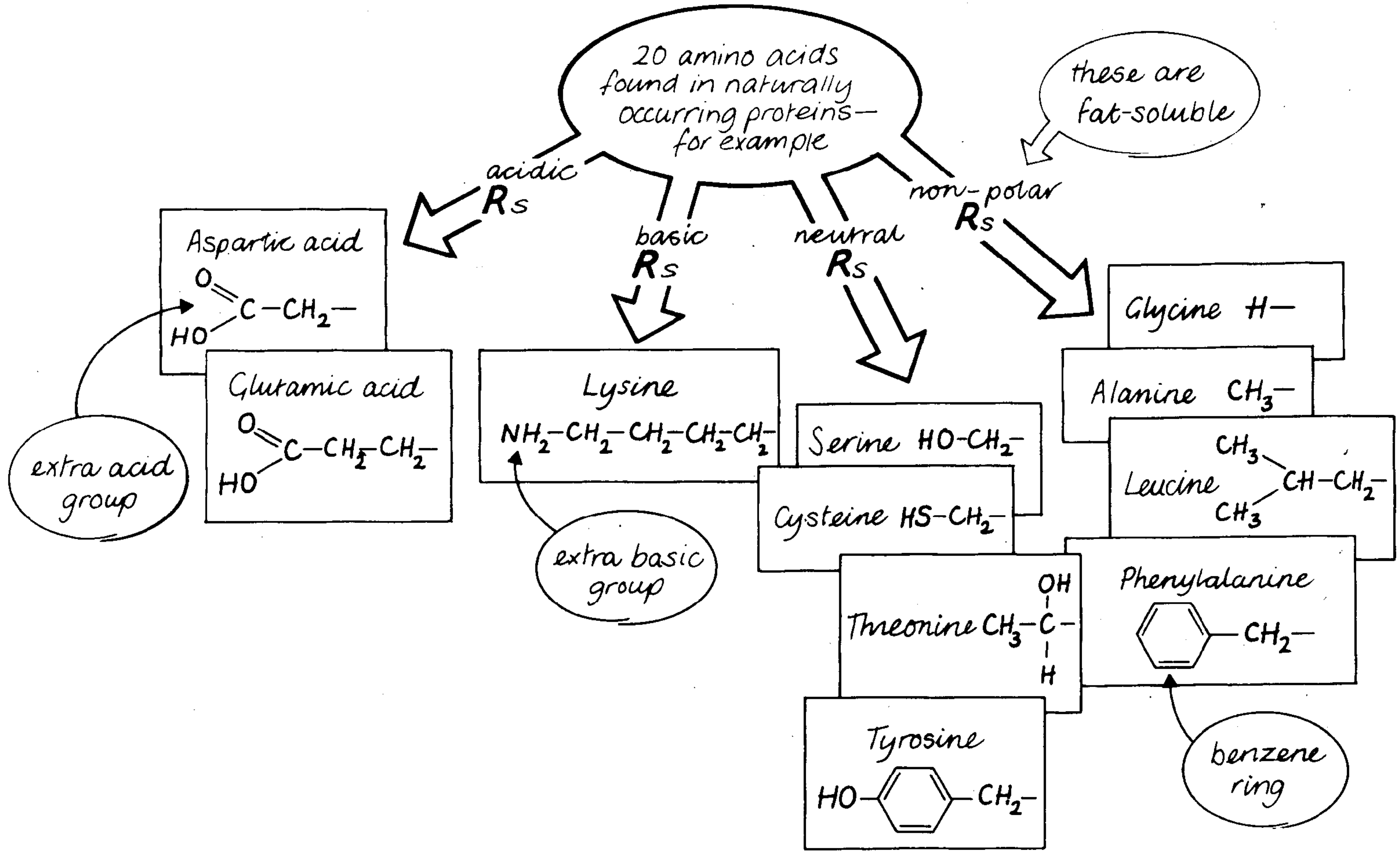


- Apart from glycine (in which the R group ≡H) all other amino acids have an **asymmetric** carbon atom. This means that they can exist in two different 3-D structures.

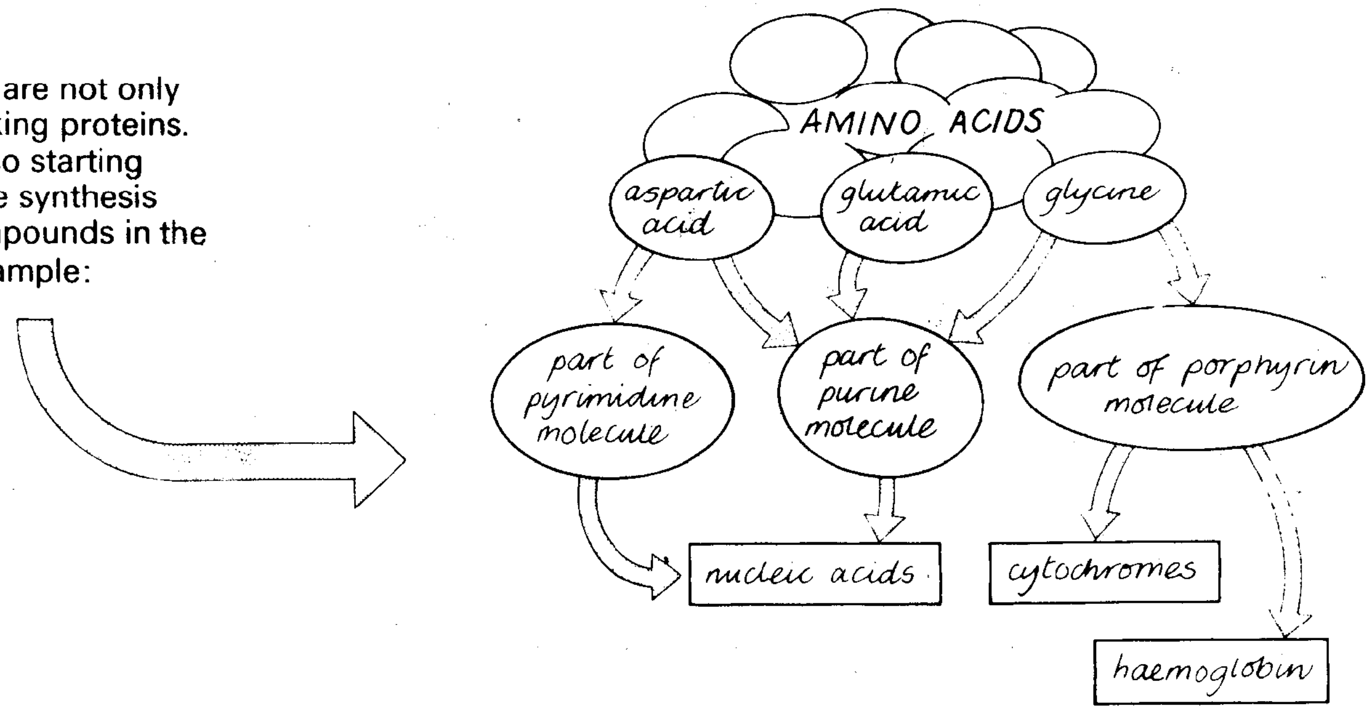


living organisms utilise almost entirely those amino-acids called L-amino acids

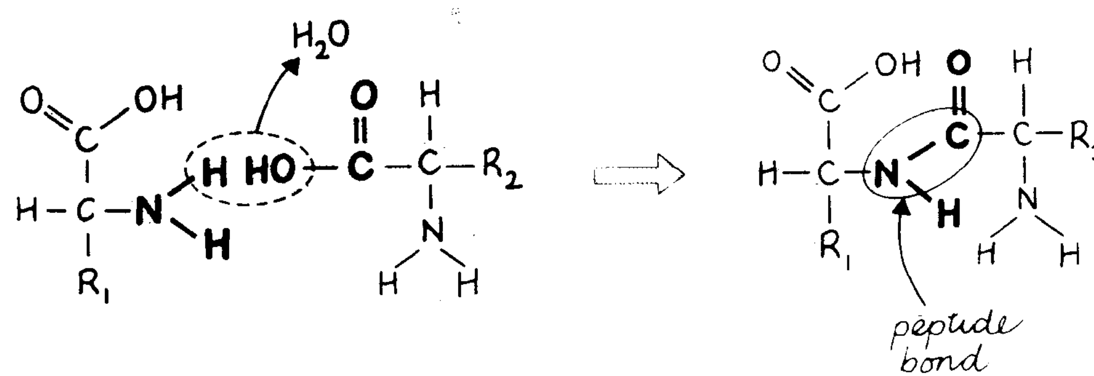
- We can put amino acids into 4 different classes depending on the nature of their side chains.



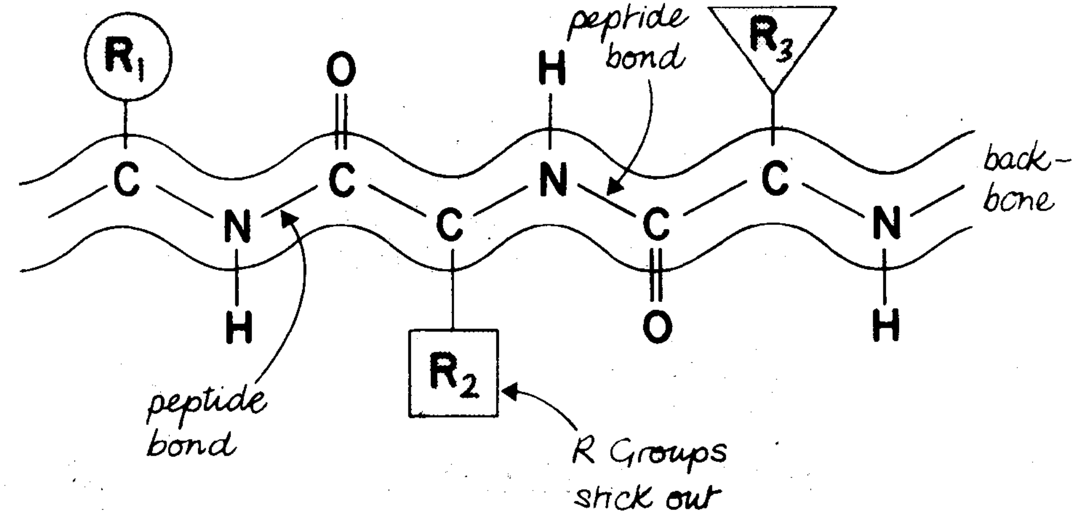
- Amino acids are not only used for making proteins. Some are also starting points for the synthesis of other compounds in the cell – for example:



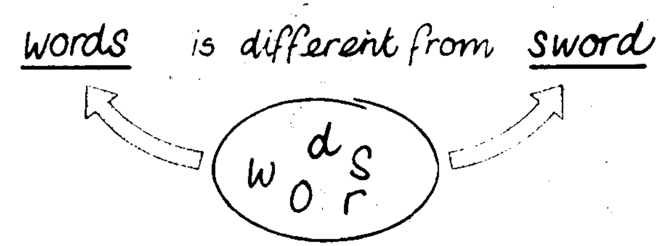
- Proteins consist of amino acids joined together by their carboxyl (acidic) and amino (basic) groups. The joins are **peptide bonds**.



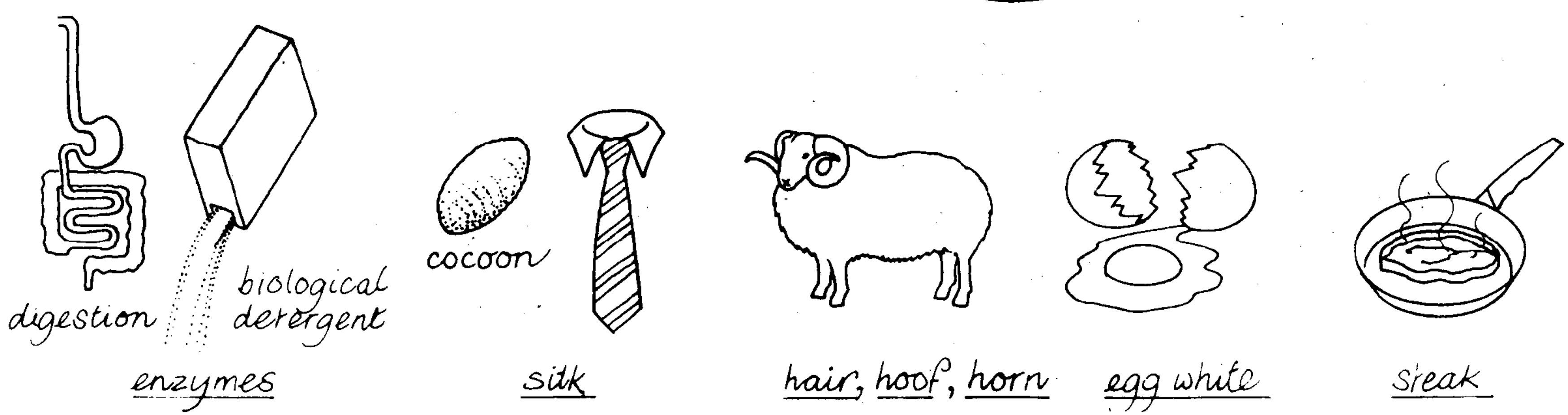
- So the protein looks like this:



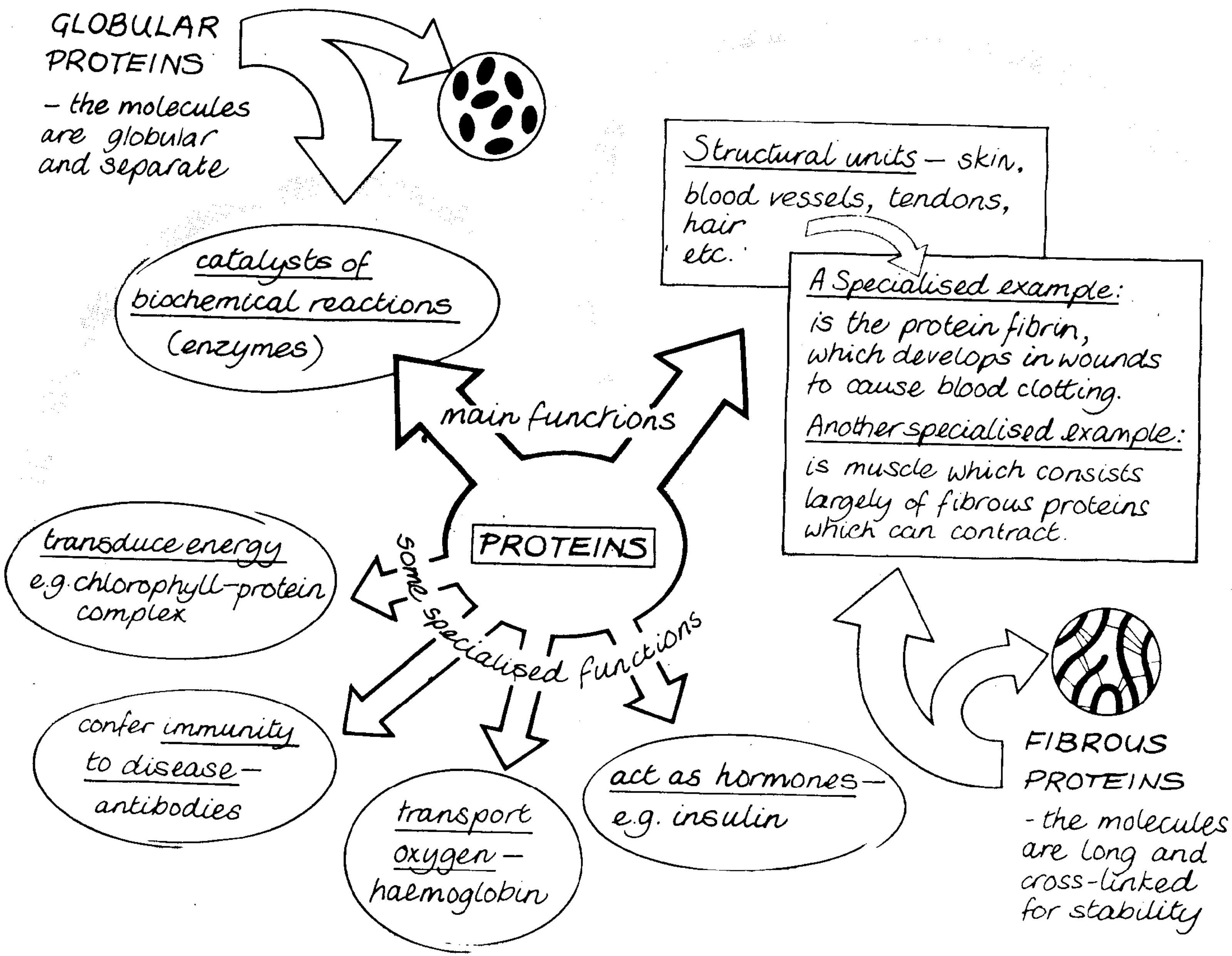
- There are lots of different proteins. Different proteins contain different combinations of amino acids like letters in (very long) words.



- Some examples:



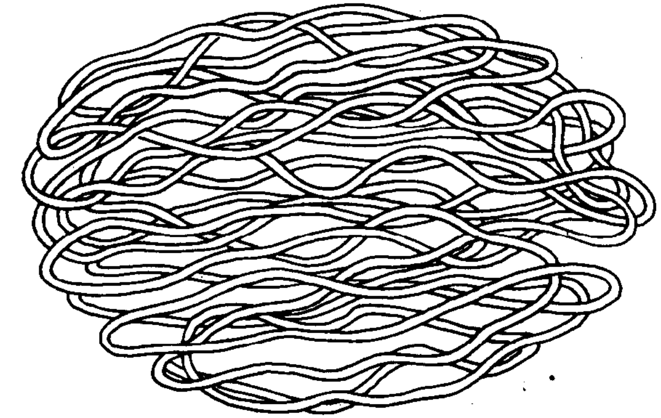
● What are proteins for? – A summary of protein functions



- Proteins vary greatly in molecular weight

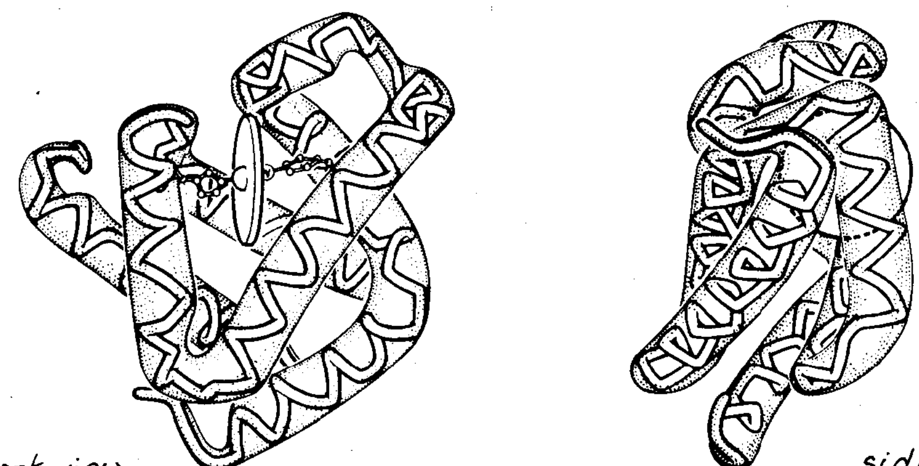
insulin
has 51 amino acids
(molecular weight 6000)

human haemoglobin
has 578 amino acids
(MW 63000)



an enzyme (urease) from bean
has 4500 amino acids
(MW 473 000)

- Proteins are not just strings of amino acids. They have a definite shape.



front view

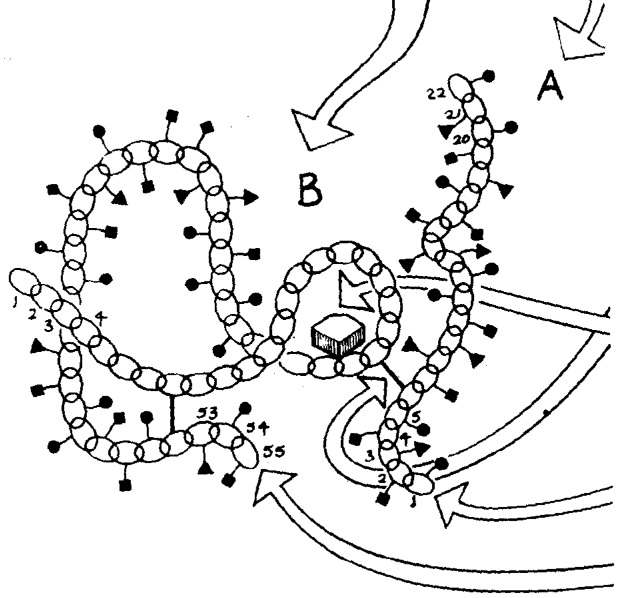
side view

Myoglobin molecule

A summary of PROTEIN STRUCTURE

1 This is an imaginary globular protein molecule. It consists of 77 amino acids (different types) linked together. (Most proteins are much bigger than this, and contain 20 different types of amino acids, but we can show most of the characteristics of typical proteins with this diagram.)

2 This protein molecule consists of 2 polypeptide chains A and B. Some proteins have only one chain. Some have several.

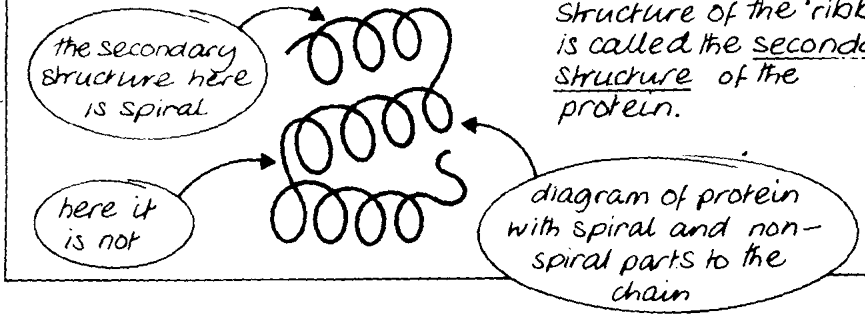


If (serine symbol) = serine (ser) (glutamic acid symbol) = glutamic acid (glu)
(lysine symbol) = lysine (lys) (glycine symbol) = glycine (gly)
(tryptophan symbol) = tryptophan (try)

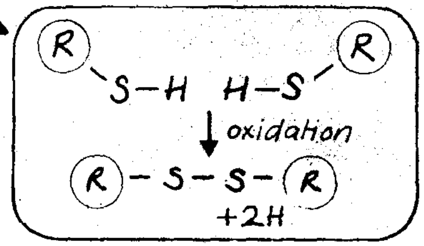
The primary structure of A is:
ser - lys - try - glu - ser - cys (teine) - lys - lys - gly - try - ser - ser - lys - gly - gly - glu - ser - gly - lys - ser - gly - ser

9 The whole 3-dimensional structure is called the <u>tertiary structure</u> of the protein. The chains do not 'flap' about at random. The tertiary structure is preset by interactions among the side groups of the amino acids. So each molecule of a particular protein has the same tertiary structure as every other molecule of that protein. If the 'normal' tertiary structure is destroyed e.g. by heat (boiling), or by strong acids or alkali or other reactive chemicals, the protein is said to be <u>denatured</u>. Denatured proteins often coagulate i.e. become insoluble.

8 The polypeptide chain is not a flat ribbon. For parts of it the amino acids are spirally arranged. This spiral is called the α-helix. The 3-dimensional structure of the 'ribbon' is called the <u>secondary structure</u> of the protein.



3 The chains are linked together by a sulphur bridge. This comes about when 2 S-containing amino acids (cysteine) link their S atoms together:



There is another S-S link holding two parts of the B chain together.

4 This is not an amino acid. It is a metal ion. Some proteins have other organic structures attached to them (often 'inside' like this one). Proteins which contain a structure which is not an amino acid are called <u>conjugated proteins</u>.

5 This is called the <u>N-terminal end</u> of the A-chain as it has a $-\overset{+}{N}H_3$ group which has not linked with another amino acid. By convention, the amino acids are <u>counted from this end</u> e.g. 'amino acid 6 of the A chain is cysteine.'

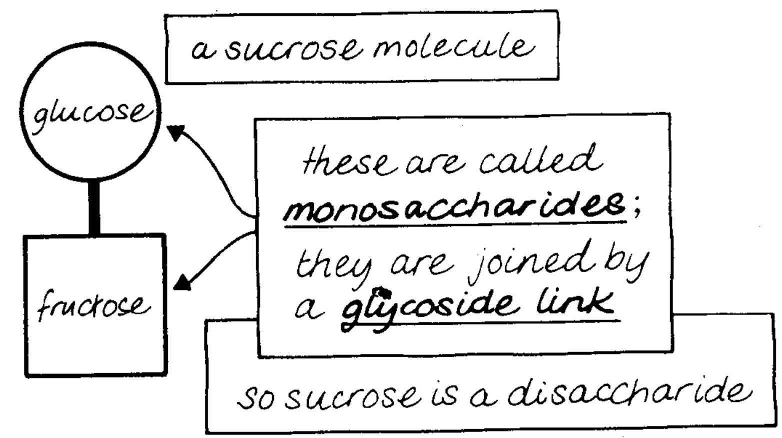
6 This is called the <u>C-terminal end</u> of the B-chain as it has a $-C{\scriptstyle\genfrac{}{}{0pt}{}{=O}{-O^-}}$ group which has not linked with another amino acid. The amino acids are <u>counted from the other end</u> e.g. 'amino acid 52 of the B-chain is cysteine.'

The other end of the B-chain <u>must be N-terminal</u>!

7 However much each chain is twisted in 3-dimensions, the amino acids have a particular <u>sequence</u> for that chain. This sequence is <u>called the primary structure</u> of the protein. It differs for different proteins.

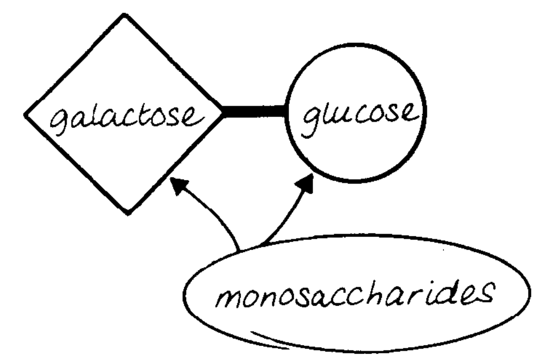
CARBOHYDRATES

- Sucrose (cane or beet sugar) is an example of a carbohydrate.



The words glyco- and sacchar- mean 'sugar'. So does the ending -ose.

- Lactose (milk sugar) is also a disaccharide.



- Starch is another carbohydrate. Each molecule has chains of hundreds or thousands of monosaccharide molecules joined together.